CLAIMS

1.   A zoom lens consisting of a first lens group having positive refracting power, a second lens group having
5   negative refracting power, a third lens group having positive refracting power, and a fourth lens group having positive refracting power, which are disposed in order from an object side, wherein the first lens group and the third lens groups are stationary, and the zoom lens
10   performs mainly variable power by shifting the second lens group in an optical axis direction, and performs correction for image position fluctuations and focusing by shifting the fourth lens group in the optical axis direction, characterized in that:
15   said first lens group is composed of five lenses: a concave lens; a convex lens with a strong convexity facing to an image side; a cemented lens composed of a concave lens with a strong concavity facing to the image side, and a convex lens; and a convex lens with a strong
20   convexity facing to the object side, which are disposed in order from the object side, and is configured so as to satisfy each of the following conditional expressions:
        (1) $1.25 < h_{1-1}/h_{1-4} < 1.55$;
        (2) $d_{1-2}/d_{1-3} < 0.4$;
25   (3) $1.65 < n_{1-2}$; and
        (4) $0.1 < H_1'/f_1 < 0.6$,
where:
        f_1 is a focal length of the first lens group;
        h_{1-i} is a paraxial ray height in the i-th surface
30   from the object side when allowing a paraxial ray parallel to an optical axis to enter the first lens

group;

d1-i is axial spacing from the i-th surface to the (i+1)-th surface in the first lens group;

n1-i is a refractive index on a d-line of the i-th

5   lens in the first lens group; and

H1' is spacing from a vertex of a surface closest to the image side in the first lens group to a principal point on the image side in the first lens group ("-" indicates the object side, and "+" indicates the image

10   side).

2.   The zoom lens as claimed in Claim 1,

characterized in that the second lens group is composed of three lenses of a concave meniscus lens with

15   a concavity facing to the image side, a double concave lens and a convex lens, which are disposed in order from the object side, and

characterized by satisfying the following conditional expression (5):

20   (5) $1.8 < (n2{-}1 + n2{-}2)/2$,

where:

n2-1 is a refractive index on a d-line of the concave meniscus lens of the second lens group; and

n2-2 is a refractive index on a d-line of the

25   double concave lens of the second lens group.

3.   The zoom lens as claimed in Claim 1,

characterized in that:

the third lens group is composed of a single

30   convex lens, and at least one surface is an aspheric surface; and

the fourth lens group is composed of a cemented lens made up of a concave meniscus lens with a concavity facing to the image side, and a double convex lens whose surface on the image side is an aspheric

5   surface, which are disposed in order from the object side, and

characterized by satisfying each of the following conditional expressions (6), (7), and (8):

(6) $-0.4 < f3/r3-2 < 0.4$;

10   (7) $-1.25 < r4-1/r4-3 < -0.8$; and

(8) $0.3 < r4-2/f4 < 0.6$,

where:

f3 is a focal length of the third lens group;

f4 is a focal length of the fourth lens group;

15   r3-2 is a radius of curvature of the image side surface of the convex lens of the third lens group;

r4-1 is a radius of curvature of the object side surface of the concave meniscus lens of the fourth lens group;

20   r4-2 is a radius of curvature of a cemented surface of the fourth lens group; and

r4-3 is a radius of curvature of a surface on the image side of the convex lens of the fourth lens group.

25 4.   The zoom lens as claimed in Claim 2, characterized in that:

the third lens group is composed of a single convex lens, and at least one surface is an aspheric surface; and

30   the fourth lens group is composed of a cemented lens made up of a concave meniscus lens with a

concavity facing to the image side, and a double convex
lens whose surface on the image side is an aspheric
surface, which are disposed in order from the object side,
and

5   characterized by satisfying each of the following
conditional expressions (6), (7), and (8):

(6) $-0.4 < f3/r3\text{-}2 < 0.4$;

(7) $-1.25 < r4\text{-}1/r4\text{-}3 < -0.8$; and

(8) $0.3 < r4\text{-}2/f4 < 0.6$,

10   where:

f3 is a focal length of the third lens group;

f4 is a focal length of the fourth lens group;

r3-2 is a radius of curvature of the image side
surface of the convex lens of the third lens group;

15   r4-1 is a radius of curvature of the object side
surface of the concave meniscus lens of the fourth lens
group;

r4-2 is a radius of curvature of a cemented surface
of the fourth lens group; and

20   r4-3 is a radius of curvature of a surface on the
image side of the convex lens of the fourth lens group.

5.   The zoom lens as claimed in Claim 1,
characterized in that:

25   the third lens group is composed of a convex
lens, and a cemented lens made up of a convex lens with a
strong convexity facing to the object side and a concave
lens with a strong concavity facing to an image side,
which are disposed in order from the object side, and at

30   least one surface is an aspheric surface; and

the fourth lens group is composed of a single

convex lens, and at least one surface is an aspheric surface, and

characterized by satisfying each of the following conditional expressions (9) and (10):

5   (9) $0.4 < h3\text{-}5/h3\text{-}1 < 0.7$; and

(10) $0.75 < f3/f3\text{-}1 < 1$,

where:

h3-i is a paraxial ray height in the i-th surface from the object side of the third lens group, when

10   allowing a paraxial ray parallel to an optical axis to enter the first lens group at a wide angle end;

f3 is a focal length of the third lens group; and

f3-1 is a focal length of the single convex lens of the third lens group.

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6.   The zoom lens as claimed in Claim 2, characterized in that:

the third lens group is composed of a convex lens, and a cemented lens made up of a convex lens with a

20   strong convexity facing to an object side and a concave lens with a strong concavity facing to an image side, which are disposed in order from the object side, and at least one surface is an aspheric surface; and

the fourth lens group is composed of a single

25   convex lens, and at least one surface is an aspheric surface, and

characterized by satisfying each of the following conditional expressions (9) and (10):

(9) $0.4 < h3\text{-}5/h3\text{-}1 < 0.7$; and

30   (10) $0.75 < f3/f3\text{-}1 < 1$,

where:

h3-i is a paraxial ray height in the i-th surface from the object side of the third lens group, when allowing a paraxial ray parallel to an optical axis to enter the first lens group at a wide angle end;

5 f3 is a focal length of the third lens group; and

f3-1 is a focal length of the single convex lens of the third lens group.

7. The zoom lens as claimed in Claim 1,

10 characterized in that:

the third lens group is composed of a single convex lens, and at least one surface is an aspheric surface; and

the fourth lens group is composed of a

15 cemented lens made up of a convex lens with a convexity facing to the object side, a concave lens, and a convex lens, which are disposed in order from the object side, and at least a surface closest to the object side is an aspheric surface, and

20 characterized by satisfying each of the following conditional expressions (11) and (12):

(11) n4-2 > 1.8; and

(12) 0.1 < f3/f4 < 0.7,

where:

25 n4-2 is a refractive index on a d-line of the concave lens of the fourth lens group;

f3 is a focal length of the third lens group; and

f4 is a focal length of the fourth lens group.

30 8. The zoom lens as claimed in Claim 2,

characterized in that:

the third lens group is composed of a single convex lens, and at least one surface is an aspheric surface; and

the fourth lens group is composed of a cemented lens made up of a convex lens with a convexity facing to the object side, a concave lens, and a convex lens, which are disposed in order from the object side, and at least a surface closest to the object side is an aspheric surface, and

characterized by satisfying each of the following conditional expressions (11) and (12):

(11) $n4\text{-}2 > 1.8$; and

(12) $0.1 < f3/f4 < 0.7$,

where:

n4-2 is a refractive index on a d-line of the concave lens of the fourth lens group;

f3 is a focal length of the third lens group; and

f4 is a focal length of the fourth lens group.

9. The zoom lens as claimed in Claim 1,
characterized in that:

the third lens group is composed of a convex lens and a cemented lens made up of a convex lens with a strong convexity facing to the object side and a concave lens with a strong concavity facing to the image side, which are disposed in order from the object side, and at least one surface is an aspheric surface; and

the fourth lens group is composed of a cemented lens made up of a double convex lens and a concave lens with a convexity facing to the image side, and at least one surface is an aspheric surface, and

characterized by satisfying each of the following conditional expressions (9), (11), and (13):

(9) $0.4 < h3\text{-}5/h3\text{-}1 < 0.7$;

(11) $n4\text{-}2 > 1.8$; and

(13) $0.75 < f3/f3\text{-}1 < 1.3$,

where:

h3-i is a paraxial ray height in the i-th surface from the object side of the third lens group, when allowing a paraxial ray parallel to an optical axis to enter the first lens group at a wide angle end;

f3 is a focal length of the third lens group;

f3-1 is a focal length of the single convex lens of the third lens group; and

n4-2 is a refractive index on a d-line of the concave lens of the fourth lens group.

10. The zoom lens as claimed in Claim 2, characterized in that:

the third lens group is composed of a convex lens and a cemented lens made up of a convex lens with a strong convexity facing to the object side and a concave lens with a strong concavity facing to the image side, which are disposed in order from the object side, and at least one surface is an aspheric surface; and

the fourth lens group is composed of a cemented lens made up of a double convex lens and a concave lens with a convexity facing to the image side, and at least one surface is an aspheric surface, and characterized by satisfying each of the following conditional expressions (9), (11), and (13):

(9) $0.4 < h3\text{-}5/h3\text{-}1 < 0.7$;

        (11)   n4-2 > 1.8; and

        (13)   0.75 < f3/f3-1 < 1.3

where:

        h3-i is a paraxial ray height in the i-th surface

5   from the object side of the third lens group, when

allowing a paraxial ray parallel to an optical axis to

enter the first lens group at a wide angle end;

        f3 is a focal length of the third lens group;

        f3-1 is a focal length of the single convex lens of

10   the third lens group; and

        n4-2 is a refractive index on a d-line of the

concave lens of the fourth lens group.

11.   An image pickup apparatus including: a zoom lens;

15   image pickup means for converting an image captured by

the zoom lens into an electric image signal; and image

control means, characterized in that:

        said image control means is configured so as to

form a new image signal subjected to coordinate

20   conversion by shifting a point on an image defined by an

image signal formed by said image pickup means, while

referring to a conversion coordinate factor previously

provided in response to a variable power rate through

said zoom lens, and output the new image signal;

25   said zoom lens is composed of a first lens group

having positive refracting power, a second lens group

having negative refracting power, a third lens group

having positive refracting power, and a fourth lens group

having positive refracting power, which are disposed in

30   order from the object side, in which the first lens group

and the third lens group are stationary, and the zoom

lens performs mainly variable power by shifting the second lens group in an optical axis direction, and performs correction for image position fluctuations and focusing by shifting the fourth lens group in the optical

5   axis direction; and

said first lens group is composed of five lenses: a concave lens; a convex lens with a strong convexity facing to an image side; a cemented lens made up of a concave lens with a strong concavity facing to the image

10   side, and a convex lens; and a convex lens with a strong convexity facing to the object side, which are disposed in order from the object side, and is characterized by satisfying each of the following conditional expressions:

(1) $1.25 < h1\text{-}1/h1\text{-}4 < 1.55$;

15   (2) $1\text{-}2/d1\text{-}3 < 0.4$;

(3) $1.65 < n1\text{-}2$; and

(4) $0.1 < H1'/f1 < 0.6$,

where:

$f1$ is a focal length of the first lens group;

20   $h1\text{-}i$ is a paraxial ray height in the i-th surface from the object side when allowing a paraxial ray parallel to an optical axis to enter the first lens group;

$d1\text{-}i$ is axial spacing from the i-th surface to the

25   (i+1)-th surface in the first lens group;

$n1\text{-}i$ is a refractive index on a d-line of the i-th lens in the first lens group; and

$H1'$ is spacing from a vertex of a surface closest to the image side in the first lens group to a principal

30   point on the image side in the first lens group ("−" indicates the object side, and "+" indicates the image

side).

12.   The image pickup apparatus as claimed in Claim 11,
characterized in that:

5   the second lens group of said zoom lens is composed
of three lenses of a concave meniscus lens with a strong
concavity facing to the image side, a double concave lens,
and a convex lens, which are disposed in order from the
object side, and satisfies the following conditional

10   expression (5):

          (5) $1.8 < (n2-1+n2-2)/2$,
where:

          n2-1 is a refractive index on a d-line of the
concave meniscus lens of the second lens group; and

15   n2-2 is a refractive index on a d-line of the
double concave lens of the second lens group.

13.   The image pickup apparatus as claimed in Claim 11,
          characterized in that:

20   the third lens group of said zoom lens is
composed of a single convex lens, and at least one
surface is an aspheric surface; and

          the fourth lens group of said zoom lens is
composed of a cemented lens made up of a concave meniscus

25   lens with a concavity facing to the image side, and a
double convex lens whose surface on the image side is an
aspheric surface, which are disposed in order from the
object side, and

          characterized by satisfying each of the following

30   conditional expressions (6), (7), and (8):

          (6) $-0.4 < f3/r3-2 < 0.4$;

(7) $-1.25 < r4\text{-}1/r4\text{-}3 < -0.8$; and

(8) $0.3 < r4\text{-}2/f4 < 0.6$,

where:

f3 is a focal length of the third lens group;

5   f4 is a focal length of the fourth lens group;

r3-2 is a radius of curvature of the image side surface of the convex lens of the third lens group;

r4-1 is a radius of curvature of the object side surface of the concave meniscus lens of the fourth lens

10   group;

r4-2 is a radius of curvature of a cemented surface of the fourth lens group; and

r4-3 is a radius of curvature of a surface on the image side of the convex lens of the fourth lens group.

15

14.   The image pickup apparatus as claimed in Claim 12, characterized in that:

the third lens group of said zoom lens is composed of a single convex lens, and at least one

20   surface is an aspheric surface; and

the fourth lens group of said zoom lens is composed of a cemented lens made up of a concave meniscus lens with a concavity facing to the image side, and a double convex lens whose surface on the image side is an

25   aspheric surface, which are disposed in order from the object side, and

characterized by satisfying each of the following conditional expressions (6), (7), and (8):

(6) $-0.4 < f3/r3\text{-}2 < 0.4$;

30   (7) $-1.25 < r4\text{-}1/r4\text{-}3 < -0.8$; and

(8) $0.3 < r4\text{-}2/f4 < 0.6$,

where:

f3 is a focal length of the third lens group;

f4 is a focal length of the fourth lens group;

r3-2 is a radius of curvature of the image side

5 surface of the convex lens of the third lens group;

r4-1 is a radius of curvature of the object side

surface of the concave meniscus lens of the fourth lens

group;

r4-2 is a radius of curvature of a cemented surface

10 of the fourth lens group; and

r4-3 is a radius of curvature of a surface on the

image side of the convex lens of the fourth lens group.

15. The image pickup apparatus as claimed in Claim 11,

15 characterized in that:

the third lens group of said zoom lens is

composed of a convex lens, and a cemented lens made up of

a convex lens with a strong convexity facing to the

object side, and a concave lens with a strong concavity

20 facing to an image side, which are disposed in order from

the object side, and at least one surface is an aspheric

surface; and

the fourth lens group of said zoom lens is

composed of a single convex lens, and at least one

25 surface is an aspheric surface, and

characterized by satisfying each of the following

conditional expressions (9) and (10):

(9) $0.4 < h3\text{-}5/h3\text{-}1 < 0.7$; and

(10) $0.75 < f3/f3\text{-}1 < 1$,

30 where:

h3-i is a paraxial ray height in the i-th surface

from the object side of the third lens group, when
allowing a paraxial ray parallel to an optical axis to
enter the first lens group at a wide angle end;

f3 is a focal length of the third lens group; and

5   f3-1 is a focal length of the single convex lens of
the third lens group.

16.   The image pickup apparatus as claimed in Claim 12,
       characterized in that:

10   the third lens group of said zoom lens is
composed of a convex lens, and a cemented lens made up of
a convex lens with a strong convexity facing to the
object side, and a concave lens with a strong concavity
facing to an image side, which are disposed in order from
15   the object side, and at least one surface is an aspheric
surface; and

           the fourth lens group of said zoom lens is
composed of a single convex lens, and at least one
surface is an aspheric surface, and

20   characterized by satisfying each of the following
conditional expressions (9) and (10):

(9) $0.4 < h3\text{-}5/h3\text{-}1 < 0.7$; and

(10) $0.75 < f3/f3\text{-}1 < 1$,

wherein:

25   h3-i is a paraxial ray height in the i-th surface
from the object side of the third lens group, when
allowing a paraxial ray parallel to an optical axis to
enter the first lens group at a wide angle end;

f3 is a focal length of the third lens group; and

30   f3-1 is a focal length of the single convex lens of
the third lens group.

17.   The image pickup apparatus as claimed in Claim 11, characterized in that:

the third lens group of said zoom lens is composed of a single convex lens, and at least one surface is an aspheric surface; and

the fourth lens group of said zoom lens is composed of a cemented lens made up of a convex lens with a convexity facing to an object side, a concave lens, and a convex lens, which are disposed in order from the object side, and at least a surface closest to the object side is an aspheric surface, and

characterized by satisfying each of the following conditional expressions (11) and (12):

(11) $n4-2 > 1.8$; and

(12) $0.1 < f3/f4 < 0.7$,

where:

n4-2 is a refractive index on a d-line of the concave lens of the fourth lens group;

f3 is a focal length of the third lens group; and

f4 is a focal length of the fourth lens group.

18.   The image pickup apparatus as claimed in Claim 12, characterized in that:

the third lens group of said zoom lens is composed of a single convex lens, and at least one surface is an aspheric surface; and

the fourth lens group of said zoom lens is composed of a cemented lens made up of a convex lens with a convexity facing to an object side, a concave lens, and a convex lens, which are disposed in order from the

object side, and at least a surface closest to the object side is an aspheric surface, and

characterized by satisfying each of the following conditional expressions (11) and (12):

5   (11)   n4-2 > 1.8; and

(12)   0.1 < f3/f4 < 0.7,

where:

n4-2 is a refractive index on a d-line of the concave lens of the fourth lens group;

10   f3 is a focal length of the third lens group; and

f4 is a focal length of the fourth lens group.

19.   The image pickup apparatus as claimed in Claim 11, characterized in that:

15   the third lens group of said zoom lens is composed of a convex lens and a cemented lens made up of a convex lens with a strong convexity facing to the object side and a concave lens with a strong concavity facing to the image side, which are disposed in order

20 from the object side, and at least one surface is an aspheric surface; and

the fourth lens group of said zoom lens is composed of a cemented lens made up of a double convex lens and a concave lens with a convexity facing to the

25 image side, and at least one surface is an aspheric surface, and

characterized by satisfying each of the following conditional expressions (9), (11), and (13):

(9)   0.4 < h3-5/h3-1 < 0.7;

30   (11)   n4-2 > 1.8; and

(13)   0.75 < f3/f3-1 < 1.3,

where:

h3-i is a paraxial ray height in the i-th surface
from the object side of the third lens group, when
allowing a paraxial ray parallel to an optical axis to
5   enter the first lens group at a wide angle end;

f3 is a focal length of the third lens group;

f3-1 is a focal length of the single convex lens of
the third lens group; and

n4-2 is a refractive index on a d-line of the
10   concave lens of the fourth lens group.

20.   The image pickup apparatus according to claim 12,
characterized in that:

the third lens group of said zoom lens is
15   composed of a convex lens and a cemented lens made up of
a convex lens with a strong convexity facing to the
object side and a concave lens with a strong concavity
facing to the image side, which are disposed in order
from the object side, and at least one surface is an
20   aspheric surface; and

the fourth lens group of said zoom lens is
composed of a cemented lens made up of a double convex
lens and a concave lens with a convexity facing to the
image side, and at least one surface is an aspheric
25   surface, characterized by satisfying each of the
following conditional expressions (9), (11), and (13):

(9) $0.4 < h3\text{-}5/h3\text{-}1 < 0.7$;

(11) $n4\text{-}2 > 1.8$; and

(13) $0.75 < f3/f3\text{-}1 < 1.3$,

30   where:

h3-i is a paraxial ray height in the i-th surface

from the object side of the third lens group, when allowing a paraxial ray parallel to an optical axis to enter the first lens group at a wide angle end;

f3 is a focal length of the third lens group;

5   f3-1 is a focal length of the single convex lens of the third lens group; and

n4-2 is a refractive index on a d-line of the concave lens of the fourth lens group.